MOVPE Growth and Optical Properties of GaN/AlGaN Superlattices as Pseudo-Ternary Alloys

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Optimizing the growth of multilayer AlGaN heterostructures is one of the key factors in improving performance of the devices such as blue-ultraviolet LEDs , photo-detectors and high power electronic devices. It is conventionally used minutes order interruption time to set up the sources while growing different Al composition of AlGaN multilayer. But minutes order growth interruption may introduce accumulation of impurities into crystal interfaces and deteriorate the crystal interface quality. To eliminate this problem sequential growth of AlGaN pseudo-ternary by using shutter control method can be selectively performed. Kikuchi et al. have reported on the growth of AlGaN pseudo-ternary by RF-MBE but the optical properties have not been discussed in detail [1]. It is another method to use superlattice structures with very thin AlGaN barrier layers as a pseudo-ternary in the growth of multi-ternary layers system. In this paper, we report the growth and optical properties of GaN/$Al_{0.58}Ga_{0.42}N$ superlattice as AlGaN pseudo-ternary alloys by metalorganic vapor phase epitaxy. High quality AlGaN pseudo-ternary alloys have been succesfully grown at very low V/III ratio (=10) by using dimethylhydrazine as nitrogen source. Effect on optical quality of superlattice by inserting seconds order interruption time between the growth of GaN and AlGaN was also studied.

GaN/$Al_{0.58}Ga_{0.42}N$ superlattices as pseudo-ternary alloys were grown at 1000 ℃ by low-pressure (160 Torr) MOVPE, using trimethylgallium and trimethylaluminium as the precursors of Ga and Al, respectively. The superlattices consist of 400 periods of GaN(0.7~4.8 nm)/$Al_{0.58}Ga_{0.42}N$ (0.4 nm) layers grown on a 20 nm AlN LT-buffer layer on a (0001) sapphire substrate. To utilize as pseudo-ternary alloys, the layer thickness of $Al_{0.58}Ga_{0.42}N$ barrier of superlattices were fixed as thin as 0.4 nm in all samples.

Figure 1 shows the 2θ-ω scan of XRD profiles from the (0002) plane of the samples. ±1st satellite diffraction peaks are clearly observed even when the period of superlattice becomes as short as 1.1 nm. It means that the crystal quality of the samples is good enough. The FWHM of ω-mode X-ray rocking curve from 0 th satellite peaks at (0002) and (20-24) plane increase with decreasing the thickness of GaN well layer. Figure 2 shows the room temperature PL spectra of the samples. It is clearly observed that PL peaks shift toward higher energies with decreasing the thickness of GaN well layer. We consider that these peaks relate to the effective band gap of the pseudo-ternary alloys. The intensity of PL peaks becomes weak and the FWHM becomes broad with increasing average of Al mole fraction in superlattice. This behaviour is similar to AlGaN alloys[2].

Figure 3 shows the room temperature PL spectra of the GaN(2.3nm)/ $Al_{0.58}Ga_{0.42}N$ (0.4nm) superlattice samples. Luminescence intensity of the sample grown with inserting one second interruption time is 3 times stronger than the sample grown without inserting interruption time. Figure 4 shows the integrated PL intensity from the samples as a function of temperature. The sample grown with inserting interruption time shows higher luminescence intensity at the whole temperature range. It is consider that non-radiative centers in the superlattice were suppresed by inserting interruption time. The energy width of density of states which occured due to fluctuation of composition or disorder at interfaces, is estimated about 12 meV from curve-fitting. This value is small enough indicating good quality of the sample.

It is suggested that the superlattice structure as a pseudo-ternary alloy is useful technique for fabricating heterostructures.

[1] A. Kikuchi, M. Yoshizawa, M. Mori, N. Fujita, K. Kushi, H. Sasamoto, and K. Kishino, J. Cryst. Growth 189/190, 109 (1998).
[2] H. S. Kim, R. A. Mair, J. Li, J. Y. Lin, and H. X. Jiang, Appl. Phys. Lett. 76, 1252 (2000)

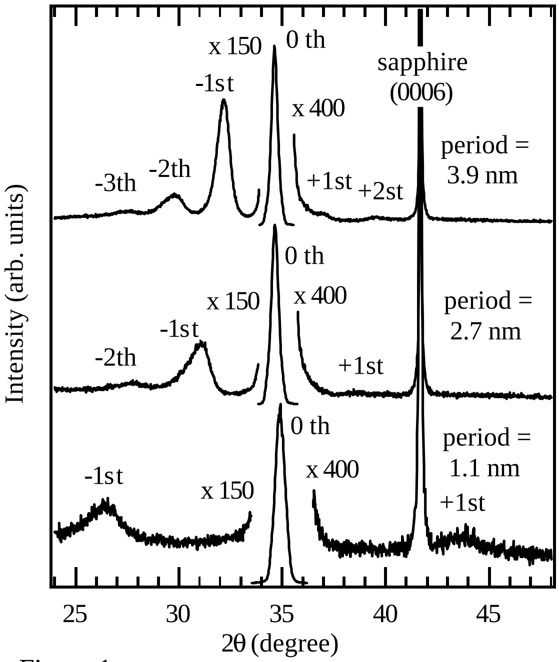

Figure 1

XRD profiles of GaN/$Al_{0.58}Ga_{0.42}N$ superlattices with difference in the thickness of a period. The thickness of $Al_{0.58}Ga_{0.42}N$ barrier layers were fixed as thin as 0.4 nm.

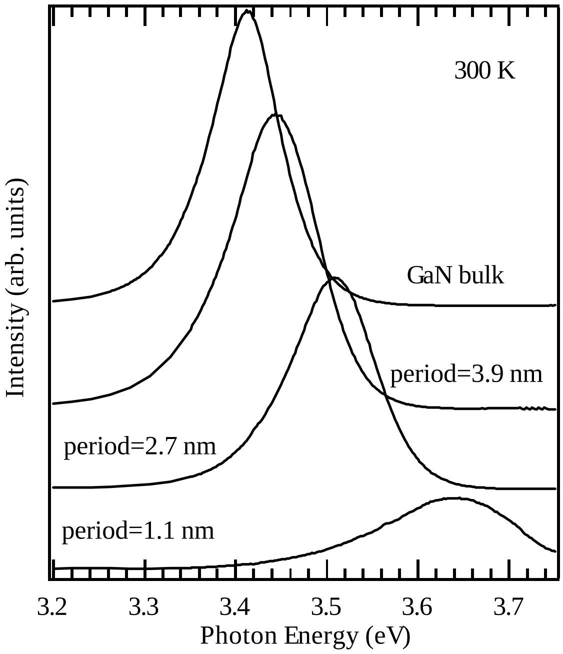

Figure 2

PL Spectra of GaN/$Al_{0.58}Ga_{0.42}N$ superlattices with difference in the thickness of a period. The thickness of $Al_{0.58}Ga_{0.42}N$ barrier layers were fixed as thin as 0.4 nm.

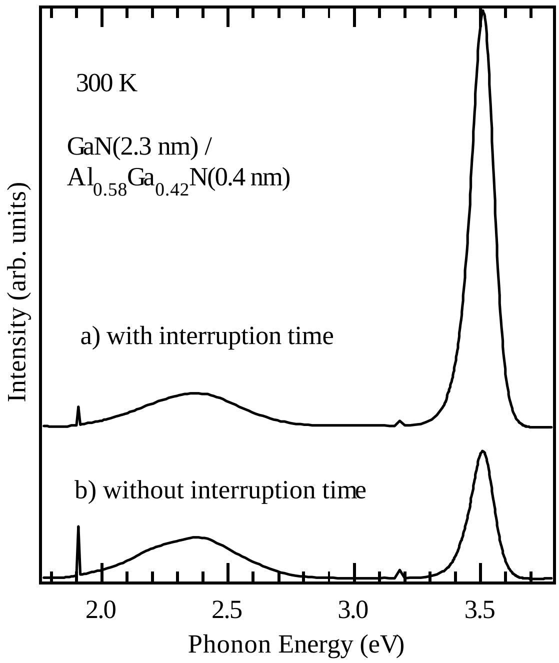

Figure 3

PL Spectra of GaN(2.3 nm)/$Al_{0.58}Ga_{0.42}N$(0.4 nm) superlattice grown a) with inserting interruption time and b) without inserting interruption time between the growth of well and

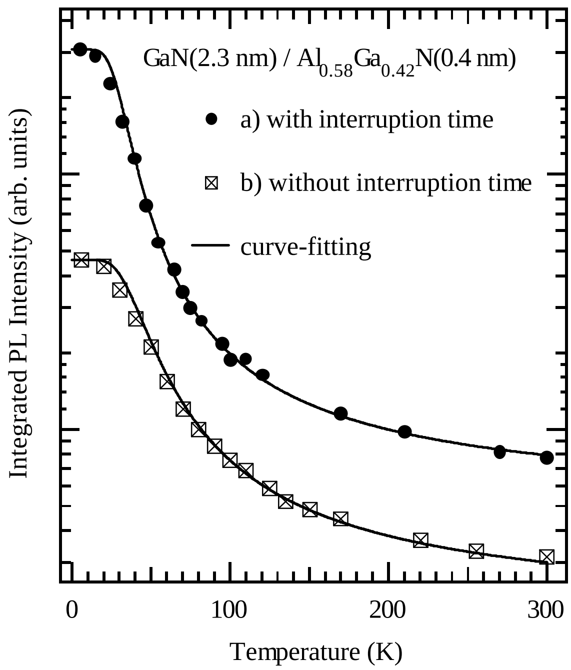

Figure 4

Temperature dependence of the integrated PL intensity of GaN(2.3 nm)/$Al_{0.58}Ga_{0.42}N$(0.4 nm) superlattice grown a) with inserting interruption time and b) without inserting interruption time between the growth of well and barrier layers.